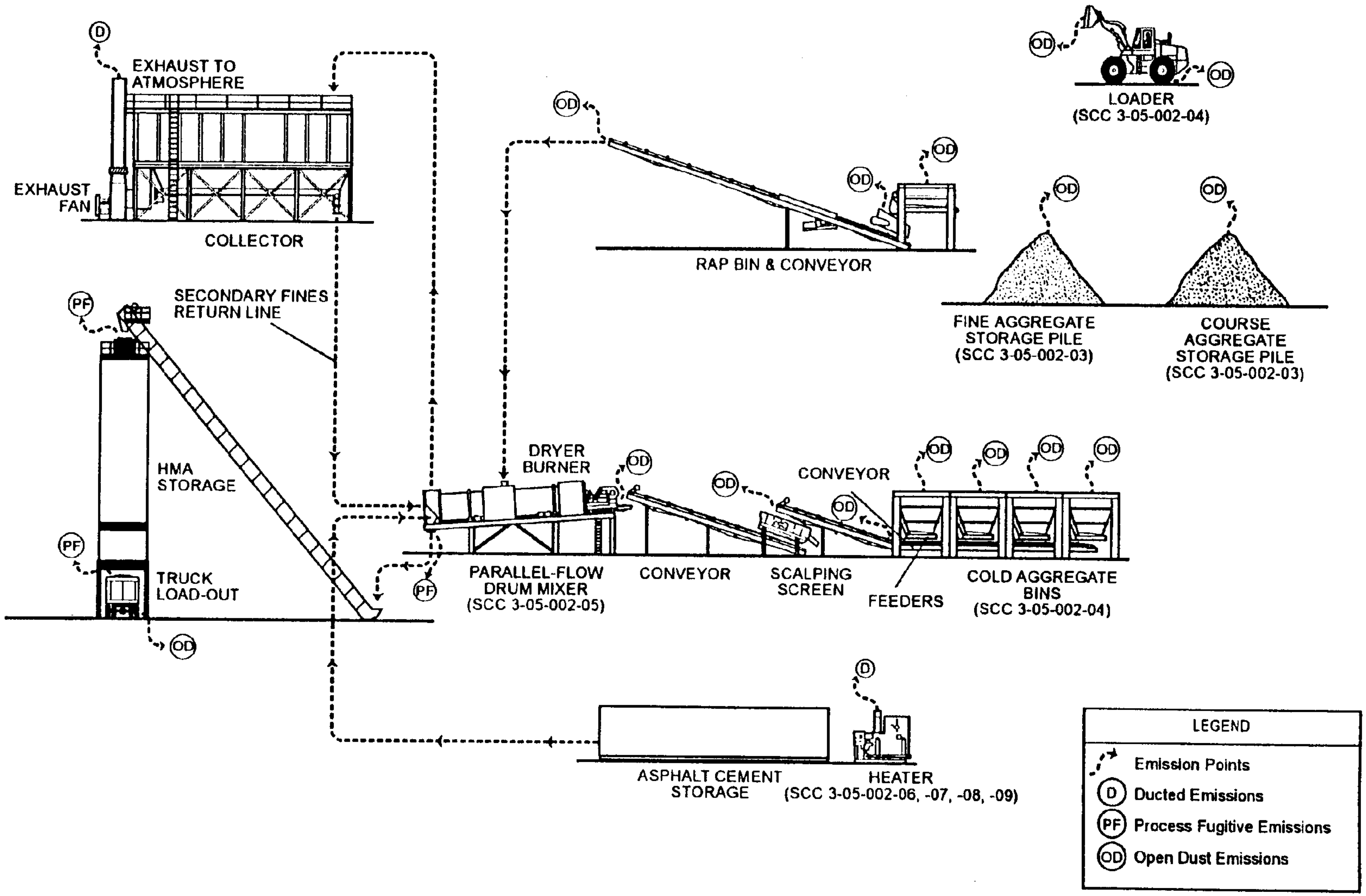

Figure 7-27. General Process Flow Diagram for Drum Mix Asphalt Paving Plants

Source: Reference 252.

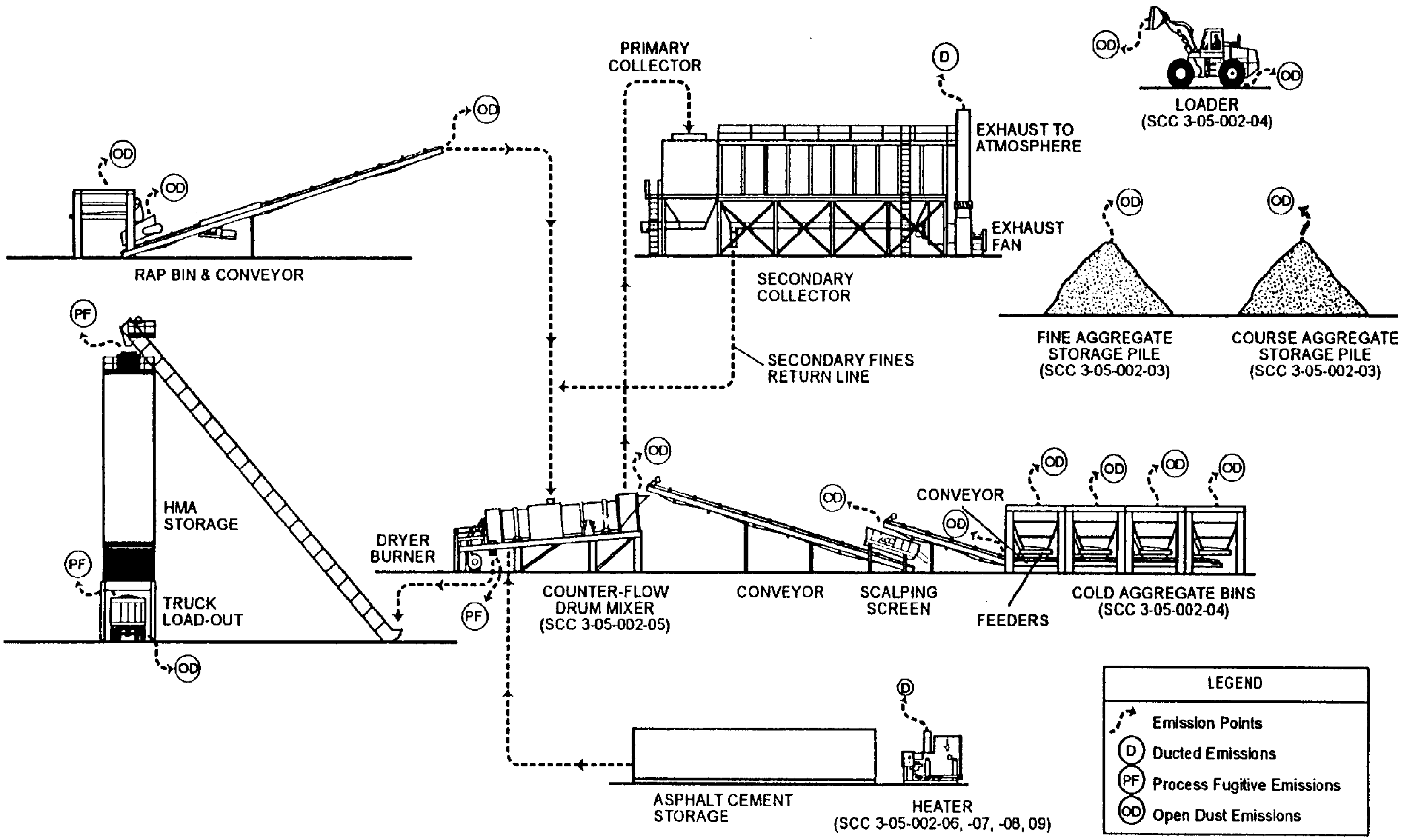

Figure 7-28. General Process Flow Diagram for Counter Flow Drum Mix Asphalt Paving Plants

Source: Reference 252.

introduced in the mixing zone midway down the drum in a lower temperature zone, along with any RAP and PM from the collectors. The mixture is discharged at the end of the drum and conveyed to a surge bin or storage silos. The exhaust gases also exit the end of the drum and pass on to the collection system.[79]

In the counterflow drum-mix type plant, the material flow in the drum is opposite or counterflow to the direction of exhaust gases. In addition, the liquid asphalt cement mixing zone is located behind the burner flame zone so as to keep the materials from direct contact with hot exhaust gases. Liquid asphalt cement flow is still controlled by a variable flow pump and is injected into the mixing zone along with any RAP and PM from primary and secondary collectors.[79]

Parallel-flow drum mixers have an advantage in that mixing in the discharge end of the drum captures a substantial portion of the aggregate dust, thereby lowering the load on the downstream collection equipment. For this reason, most parallel flow drum mixers are followed only by primary collection equipment (usually a baghouse or venturi scrubber). However, because the mixing of aggregate and liquid asphalt cement occurs in the hot combustion product flow, organic emissions (gaseous and liquid aerosol) from parallel-flow drum mixers may be greater than in other processes.[79]

On the other hand, because the liquid asphalt cement, virgin aggregate, and RAP are mixed in a zone removed from the exhaust gas stream, counterflow drum-mix plants will likely have organic emissions (gaseous and liquid aerosol) that are lower than those from parallel-flow drum-mix plants. A counterflow drum-mix plant can normally process RAP at ratios up to 50 percent with little or no observed effect on emissions. Today's counterflow drum-mix plants are designed for improved thermal efficiencies.[79]

Of the 3,600 active hot-mix asphalt plants in the United States, approximately 2,300 are batch-mix plants, 1,000 are parallel-flow drum-mix plants, and 300 are counterflow drum-mix plants. About 85 percent of plants being built today are of the counterflow drum-mix design; batch-mix plants and parallel-flow drum-mix plants account for 10 and 5 percent, respectively.[79]

One major advantage of both types of drum-mix plants is that they can produce material containing higher percentages of RAP than batch-mix plants can produce. The use of RAP significantly reduces the amount of new (virgin) rock and asphalt cement needed to produce hot-mix asphalt. With the greater veiling of aggregate, drum-mix plants are more efficient than batch-mix plants at transferring heat and achieving proper mixing of recycled asphalt and virgin materials.[253]

7.9.2 Benzene Emissions from the Hot-Mix Asphalt Production

Emissions of benzene from hot-mix asphalt plants occur from the aggregate rotary dryers and the asphalt heaters (due to fuel combustion). In Figure 7-26, the emission point for the rotary dryer is indicated by SCC 3-05-002-01, and the emission point for the heater is indicated by SCC 3-05-002-06, -07, -08, and -09. Note that most of the emission points in Figures 7-26 and 7-27 are sources of particulate matter. Most plants employ some form of mechanical collection, typically cyclones, to collect aggregate particle emissions from the rotary dryers. However, these cyclones would have a minimal collection efficiency for benzene.

Other types of controls installed at asphalt hot-mix plants, primarily to control PM emissions, include wet scrubbers or baghouses.[253] These controls are expected to have some effect on reducing benzene emissions; however, the control efficiencies are not known.

Table 7-15 presents four emission factors for the rotary dryer at a hot-mix asphalt plant.[3,254-263] The factors range from $1.41\text{x}10^{-4}$ lb/ton ($7.04\text{x}10^{-5}$ kg/Mg) to $1.95\text{x}10^{-5}$ lb/ton ($9.75\text{x}10^{-6}$ kg/Mg) and differ in the type of fuel burned to heat the dryer (LPG, oil, natural gas, or diesel) and the type of control device used (cyclone, baghouse, wet scrubber, or uncontrolled). Table 7-15 also presents one emission factor for an

TABLE 7-15. EMISSION FACTORS FOR HOT-MIX ASPHALT MANUFACTURE

SCC and Description	Emissions Source	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Factor Rating	Reference
3-05-002-01 Petroleum Industry-Asphalt Concrete-Rotary Dryer	Rotary Dryer, LPG-fired	Uncontrolled	$5.35x10^{-4}$ ($2.68x10^{-4}$)	C	254-256
	Rotary Dryer, oil-fired	Multiple cyclone	$7.70x10^{-5}$ ($3.85x10^{-5}$)	C	3, 257
	Rotary Dryer, natural gas- or oil-fired	Baghouse with single cyclone, knock-out box, or multiple cyclone	$2.08x10^{-4}$ ($1.04x10^{-4}$)	B	258-261
	Rotary Dryer, natural gas- or diesel-fired	Wet scrubber	$1.95x10^{-5}$ ($9.75x10^{-6}$)	C	262, 263
3-05-002-08 Petroleum Industry-Asphalt Concrete-Asphalt heater-Distillate oil	Asphalt Heater, diesel-fired	Uncontrolled	$1.50x10^{-4}$ ($7.50x10^{-5}$)	D	254

[a] Emission factors are in lb (kg) of benzene emitted per ton (Mg) of hot-mix asphalt produced.

uncontrolled asphalt heater fired with diesel fuel. The source tests from which these emission factors were derived all use CARB Method 401 for sampling.

No regulations were identified that require control of benzene emissions at hot mix asphalt plants.

7.10 OPEN BURNING OF BIOMASS, SCRAP TIRES, AND AGRICULTURAL PLASTIC FILM

Open burning involves the burning of various materials in open drums or baskets, in fields or yards, and in large open drums or pits. Materials commonly disposed of in this manner include municipal waste, auto body components, landscape refuse, agricultural field refuse, wood refuse, bulky industrial refuse, and leaves. This section describes the open burning of biomass, scrap tires, and agricultural plastic film, and their associated benzene emissions.

7.10.1 Biomass Burning

Fires are known to produce respirable PM and toxic substances. Concern has even been voiced regarding the effect of emissions from biomass burning on climate change.[264] Burning wood, leaves, and vegetation can be a source of benzene emissions. In this document, the burning of any wood, leaves, and vegetation is categorized as biomass burning, and includes yard waste burning, land clearing/burning and slash burning, and forest fires/prescribed burning.[265]

Part of the complexity of fires as a source of emissions results from the complex chemical composition of the fuel source. Different woods and vegetation are composed of varying amounts of cellulose, lignin, and extractives such as tannins, and other polyphenolics, oils, fats, resins, waxes, and starches.[266] General fuel type categories in the National Fire-Danger Rating (NFDR) System include grasses, brush, timber, and slash (residue that remains on a site after timber harvesting).[266] The flammability of these fuel types depends upon plant species, moisture content, whether the plant is alive or dead at the time of burning, weather, and seasonal variations.

Pollutants from the combustion of biomass include CO, NO_x, sulfur oxides (SO_x), oxidants, polycyclic organic matter (POM), hydrocarbons, and PM. The large number of combustion products is due, in part, to the diversity of combustion processes occurring simultaneously within a fire-flaming, smoldering, and glowing combustion. These processes are distinct combustion processes that involve different chemical reactions that affect when and what pollutants will be emitted during burning.[266]

Emission factor models (based on field and laboratory data) have been developed by the U.S. Forest Service. These models incorporate variables such as fuel type and combustion types (flaming or smoldering). Because ratios of toxic air substances are correlated with the release of other primary PICs (such as CO), the models correlate benzene with CO emissions.[266] These emission factor models were used to develop emission factors for the biomass burning sub-categories described in the following sections.[265]

Because of the potential variety in the fuel source and the limited availability of emission factors to match all possible fuel sources, emissions estimates may not necessarily represent the combustion practices occurring at every location in the United States. Therefore, localized practices of such parameters as type of wood being burned and control strategies should be carefully compared.[265]

Yard Waste Burning

Yard waste burning is the open burning of such materials as landscape refuse, wood refuse, and leaves in urban, suburban, and residential areas.[265] Yard waste is often burned in open drums, piles, or baskets located in yards or fields. Ground-level open burning emissions are affected by many variables, including wind, ambient temperature, composition and moisture content of the material burned, and compactness of the pile. It should be noted that this type of outdoor burning has been banned in certain areas of the United States, thereby reducing emissions from this subcategory.[265,267] An emission factor for yard waste is shown in Table 7-16.[265,266]

Land Clearing and Slash Burning

This subcategory includes the burning of organic refuse (field crops, wood, and leaves) in fields (agricultural burning) and wooded areas (slash burning) in order to clear the land. Burning as part of commercial land clearing often requires a permit.[265] Emissions from organic agricultural refuse burning are dependent primarily on the moisture content of the refuse and, in the case of field crops, on whether the refuse is burned in a headfire or a backfire.[267] Other variables, such as fuel loading (how much refuse material is burned per unit of land area) and how the refuse is arranged (piles, rows, or spread out), are also important in certain instances.[267] Emission factors for land clearing/burning and slash burning are shown in Table 7-16.[265,266]

Forest Fires/Prescribed Burning

A forest fire (or wildfire) is a large-scale natural combustion process that consumes various ages, sizes, and types of outdoor vegetation.[268] The size, intensity, and even occurrence of a forest fire depend on such variables as meteorological conditions, the species and moisture content of vegetation involved, and the weight of consumable fuel per acre (fuel loading).[268]

Prescribed or broadcast burning is the intentional burning of forest acres as part of forest management practices to achieve specific wildland management objectives. Controlled burning can be used to reduce fire hazard, encourage wildlife habitat, control insects, and enhance the vigor of the ecosystem.[266] Prescribed burning occurs thousands of times annually in the United States, and individual fires vary in size from a fraction of an acre

TABLE 7-16. SUMMARY OF BENZENE EMISSION FACTORS FOR BIOMASS BURNING

AMS Code	Emission Source	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Emission Factor Rating
26-10-030-000	Yard Waste Burning	Uncontrolled	1.10 (5.51×10^{-1})	U
28-01-500-000	Land Clearing/Burning	Uncontrolled	9.06×10^{-1} (4.53×10^{-1})	U
28-10-005-000	Slash (Pile) Burning	Uncontrolled	9.06×10^{-1} (4.53×10^{-1})	U

Source: References 265 and 266.

[a] Factors are in lb (kg) of benzene emitted per ton (Mg) of biomass burned.

AMS = Area and mobile source.

to several thousand acres. Prescribed fire use is often seasonal, which can greatly affect the quantity of emissions produced.[266]

HAP emission factors for forest fires and prescribed burning were developed using the same basic approach for yard waste and land clearing burning, with an additional step to further classify fuel types into woody fuels (branches, logs, stumps, and limbs), live vegetation, and duff (layers of partially decomposed organic matter).[265] In addition to the fuel type, the methodology was altered to account for different phases of burning, namely, flaming and smoldering.[265] The resulting emission factors are shown in Table 7-17.

7.10.2 Tire Burning

Approximately 240 million vehicle tires are discarded annually.[269] Although viable methods for recycling exist, less than 25 percent of discarded tires are recycled; the remaining 175 million are discarded in landfills, stockpiles, or illegal dumps.[269] Although it is illegal in many states to dispose of tires using open burning, fires often occur at tire stockpiles and through illegal burning activities.[267] These fires generate a huge amount of heat and are difficult to extinguish (some tire fires continue for months).

Table 7-18 contains benzene emission factors for chunk tires and shredded tires.[267] When estimating emissions from an accidental tire fire, it should be kept in mind that emissions from burning tires are generally dependent on the burn rate of the tire. A greater potential for emissions exists at lower burn rates, such as when a tire is smoldering rather than burning out of control.[267] The fact that the shredded tires have a lower burn rate indicates that the gaps between tire materials provide the major avenue of oxygen transport. Oxygen transport appears to be a major, if not the controlling mechanism for sustaining the combustion process.

TABLE 7-17. SUMMARY OF BENZENE EMISSION FACTORS FOR BIOMASS BURNING BY FUEL TYPE

AMS Code	Emission Source	Fuel Type	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Emission Factor Rating
28-10-001-000	Forest Fires	Fire wood	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Small wood	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Large wood (flaming)	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Large wood (smoldering)	Uncontrolled	2.52 (1.26)	U
		Live vegetation	Uncontrolled	1.48 (7.4×10^{-1})	U
		Duff (flaming)	Uncontrolled	2.52 (1.26)	U
28-10-015-000	Prescribed Burning (Broadcast)	Fire wood	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Small wood	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Large wood (flaming)	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Large wood (smoldering)	Uncontrolled	2.52 (1.26)	U
		Live vegetation	Uncontrolled	1.48 (7.4×10^{-1})	

(continued)

TABLE 7-17. CONTINUED

AMS Code	Emission Source	Fuel Type	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Emission Factor Rating
		Duff (flaming)	Uncontrolled	6.6×10^{-1} (3.3×10^{-1})	U
		Duff (smoldering)	Uncontrolled	2.52 (1.26)	U

Source: References 265 and 266.

[a] Factors are in lb (kg) of benzene emitted per ton (Mg) of biomass burned.

AMS = Area and mobile source.

TABLE 7-18. SUMMARY OF BENZENE EMISSION FACTORS FOR OPEN BURNING OF TIRES

SCC	Emission Source	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Emission Factor Rating
5-03-002-03	Chunk Tires	Uncontrolled	3.05[b,c] (1.53)	C
	Shredded Tires	Uncontrolled	3.86[b,c] (1.93)	C

Source: Reference 267.

[a] Factors are in lb (kg) of benzene emitted per ton (Mg) of tires burned.
[b] Values are weighted averages because of different burn rates.
[c] The data used to develop the emission factor are averaged over six sets of VOST tubes per day taken over two days.

7.10.3 Agricultural Plastic Film Burning

Agricultural plastic film is plastic film that has been used for ground moisture and weed control. The open burning of large quantities of plastic film commonly coincides with the burning of field crops. The plastic film may also be gathered into large piles and burned, with or without forced air (an air curtain).[267]

Emissions from burning agricultural plastic film are dependent on whether the film is new or has been exposed to vegetation and possibly pesticides. Table 7-19 presents emission factors for benzene emissions from burning new and used plastic film in piles with and without forced air (i.e., air is forced through the pile to simulate an air curtain).[267]

TABLE 7-19. SUMMARY OF BENZENE EMISSION FACTORS FOR OPEN BURNING OF AGRICULTURAL PLASTIC FILM

SCC	Emission Source	Control Device	Emission Factor lb/ton (kg/Mg)[a]	Emission Factor Rating
5-03-002-02	Unused Plastic	Uncontrolled[b]	9.55×10^{-5} (4.77×10^{-5})	C
		Forced Air[c]	5.75×10^{-5} (2.87×10^{-5})	C
	Used Plastic	Uncontrolled[b]	2.47×10^{-5} (1.23×10^{-5})	C
		Forced Air[c]	4.88×10^{-5} (2.44×10^{-5})	C

Source: Reference 267.

[a] Factors are in lb (kg) of benzene emitted per ton (Mg) of agricultural plastic film burned.
[b] Emission factors are for agricultural plastic film gathered in a pile and burned.
[c] Emission factors for agricultural plastic film burned in a pile with a forced air air current.